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THE EFFECTS OF GBU-15 CRUCIFORM WING WEAPON CANARD SIZING ON THE DRAG AND LONGITUDINAL STABILITY OF THE F-4 AIRCRAFT

AIRCRAFT COMPATIBILITY BRANCH
MUNITIONS DIVISION

NOVEMBER 1976

FINAL REPORT: JANUARY 1976-NOVEMBER 1976

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AIR FORCE ARMAMENT LABORATORY
AIR FORCE SYSTEMS COMMAND • UNITED STATES AIR FORCE
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

An aerodynamic analysis has been conducted for carriage of two designs of GBU-15 CWW's on the F-4 aircraft. The analysis was to determine the effects of the GBU-15 Cruciform Wing Weapon (CWW) canard sizing on the drag and longitudinal stability of the F-4 aircraft. The GBU-15 CWW canard redesign from a 46-inch span to a 29-inch span canard equated to a Drag Index reduction, per GBU-15 CWW, of 2.6. The Stability Index Number, per GBU-15 CWW, was reduced by approximately 50 percent.

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PREFACE

This report documents the GBU-15 Cruciform Wing Weapon canard sizing effects on the drag and longitudinal stability of the F-4 aircraft. Captain Jack L. Kincart (DLJC) served as project engineer for the study. The study was initiated in June 1976 and was completed in November 1976.

This report has been reviewed by the Information Officer (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS it will be available to the general public, including foreign nations.

This report has been reviewed and is approved for publication.

FOR THE COMMANDER

William F. Brockman

WILLIAM F. BROCKMAN, Colonel, USAF
Chief, Munitions Division

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LIST OF ABBREVIATIONS, ACRONYMS AND SYMBOLS

C_{D_T}	Aircraft trim drag coefficient, $\frac{drag}{q_\infty S}$
cg	Center-of-gravity location, percent MAC
CWW	Cruciform Wing Weapon
DI	Drag Index, ΔC_D x 10 x S
Drag Count	Drag Coefficient x 10,000
H	Altitude, feet
M	Free Stream Mach number
MAC	Theoretical Mean Aerodynamic Chord
NP	Neutral Point location, percent MAC
q_∞	Free stream dynamic pressure
S	Wing reference area, 530 square feet
SIN	Stability Index Number
α_{W_T}	Wing chord angle of attack at trim conditions, deg
δ_{S_T}	Stabilator angle of attack at trim conditions, deg
$\Delta\alpha_{W_T}$	Incremental trim wing angle of attack, deg
$\Delta\delta_{S_T}$	Incremental trim stabilator angle, deg

SECTION I

INTRODUCTION

In recent years, nonnuclear weapon design has evolved from the conventional unguided stores such as dispensers, firebombs, and general purpose bombs to highly sophisticated guided weapon systems. Many of these systems incorporate laser or electro-optical guidance packages, autopilots, and movable wing/canard/tail combinations for free flight maneuvering. Examples of the sophisticated weapon systems are the GBU-15 Planar Wing Weapon (PWW), GBU-15 Cruciform Wing Weapon (CWW) and the Pavestorm I and II.

Many problems have been found with the guided weapons when investigating all aspects of aircraft/store compatibility. Typical problem areas have been with store separation (Reference 1), store mounting, and degradations to aircraft stability. This report will deal with one aspect of the problems that can arise with the new sophisticated guided weapon systems, that is, degradations to performance and stability due to carriage of the GBU-15 CWW on the F-4 aircraft.

The initial design of the GBU-15 CWW was configured with 51-inch span canards and 59-inch span wing assembly in the carriage position. This design of the GBU-15 CWW proved to exhibit unsafe separation characteristics from the F-4 aircraft. A second iteration redesign of the canards and further analysis proved that the 31-inch span canard GBU-15 CWW exhibited safe separation characteristics from the F-4 aircraft (Reference 1).

This report is a subsequent performance and stability analysis of the initial and redesigned GBU-15 CWW on the F-4 aircraft. The purpose of this report is to determine and compare the effects on longitudinal stability and drag characteristics of the F-4 aircraft due to carriage of the large canard GBU-15 CWW (Figure 1) and the small canard GBU-15 CWW (Figure 2). Data were utilized from two separate wind tunnel force tests to determine the degradations in longitudinal stability and drag characteristics. Both tests were conducted in the Aerodynamic Wind Tunnel (4T) of the AEDC Propulsion Wind Tunnel Facility utilizing 0.05 scale models. The 0.05 scale model of the large canard GBU-15 CWW varied from the initial design. The wind tunnel model was scaled for 46-inch span canards and 61-inch span wing assembly (Figure 3). The initial design incorporated 51-inch span canards and 59-inch span wing assembly. The 0.05 scale model of the small canard GBU-15 CWW also varied from the second iteration design. The wind tunnel model was scaled for 29-inch span canards and 61-inch span wing assembly, whereas, the second iteration design had 31-inch span canards and 59-inch span wing assembly (Figure 4). As shown in Figures 1 and 2, the small canard GBU-15 CWW wind tunnel model had faired leading edges of the canards and

wings. The large canard GBU-15 CWW wind tunnel model did not. However, for the purpose of this analysis, and the conclusions that will be discussed later, the differences are not important. Further details of the wind tunnel tests can be found in References 2 and 3.

It should be noted that carriage of the GBU-15 CWW on the F-4C/D aircraft is possible; it has been determined that Stability Index Numbers and Drag Indexes for a particular store are the same on the F-4C/D/E models (References 4 and 5).

SECTION II

DATA ANALYSIS

The data analysis assumed a representative F-4 gross weight of 52,300 pounds. The trimmed aerodynamic characteristics were determined for altitudes of sea level, 10,000, 20,000, and 30,000 feet from wind tunnel data referenced to a cg location of 33 percent of the theoretical mean aerodynamic chord (MAC). The Mach numbers range from 0.6 to 1.3. The wind tunnel data in this report are corrected to full scale F-4 aircraft.

Figures 5 through 16 present incremental aerodynamic trim conditions versus Mach number and altitude. The baseline configuration was the F-4 with two 370-gallon wing tanks and two armament pylons. Two sets of data are presented on each figure. One set of data, labeled small canards, are the increments due to the GBU-15 CWW with small canards, and likewise for the set of data labeled large canards. Figures 17 through 20 present total aircraft neutral point location versus Mach number and altitude. Two sets of data are presented on each figure. One set of data, labeled small canards, is the F-4 aircraft with 370-gallon wing tanks on stations 1 and 9 and the GBU-15 CWW (small canards) with MAU-12B/A pylons on stations 2 and 8. All other stations are empty. The second set of data presented, labeled large canards, is the same except that the GBU-15 CWW (large canards) are substituted on stations 2 and 8. Any increments between the two curves in each figure, therefore, are due only to the canard sizing on the GBU-15 CWW.

Figures 5 through 16 are the incremental trim angle of attack, incremental stabilator angle to trim and incremental trim drag coefficient versus Mach number curves. Incremental trim drag coefficient versus Mach number and altitude curves are presented in Figures 13 through 16. As illustrated in these figures, the incremental trim drag coefficient was slightly decreased by the smaller canards. The average decrease in drag was about 10 drag counts for the normal flight envelope of the F-4 aircraft. Ten drag counts equate to a Drag Index of 5.3. As a comparison, the Drag Index of a MK82 LDGP is 1.1.

Figures 17 through 20 present neutral point versus Mach number and altitude. As seen in these figures, the F-4 aircraft is considerably more stable in the longitudinal plane subsonically with the small canard GBU-15 CWW. Depending upon Mach number and altitude, the aircraft neutral point for carriage of the small canard GBU-15 CWW was 1 to 5 percent MAC further aft of the aircraft neutral point for the large canard GBU-15 CWW. In the transonic region, at 10,000 and 20,000 feet, the neutral point of the aircraft with both GBU-15 CWW designs fluctuated such that neither had a clear advantage over the other. It was only at sea level and 30,000 feet altitude that the aircraft neutral point with the small canard GBU-15 CWW was consistently aft (more stable) of the aircraft neutral point with the

large canard GBU-15 CWW. Supersonic data for the smaller canard GBU-15 CWW extended to only M = 1.1, therefore, a thorough comparison to the large canard GBU-15 CWW could not be made. However, the trends from transonic to M = 1.1 clearly indicate that the aircraft neutral point with the smaller canard GBU-15 CWW is aft of the aircraft neutral point with the large canard GBU-15 CWW.

For an example to relate to the Stability Index Number System (SIN), an F-4 configuration of two 370-gallon wing tanks and two GBU-15 CWW's was investigated. From the data in Figure 19, the aircraft neutral point location with the large canard GBU-15 CWW is 31.3 percent MAC for M = 0.85. This neutral point equates to a SIN of 277.5 for the total aircraft. Subtracting SIN's for the two armament pylons and two wing tank/pylon combinations from 277.5 and dividing by two, gives a SIN for one large canard GBU-15 CWW of about 102. From the same figure and Mach number, the corresponding aircraft neutral point location with the small canard GBU-15 CWW is 33 percent MAC. Thirty-three percent MAC equates to a total aircraft SIN of 168.8. Following the identical steps explained above, the SIN for one small canard GBU-15 CWW is 47.5. In effect, the redesign of the canards decreased the SIN of the GBU-15 CWW by over 50 percent. For a more thorough examination of the SIN system and Drag Index system, refer to Reference 6.

SECTION III

CONCLUSIONS

The aerodynamic analysis of the effects of the wind tunnel model canard redesign on the drag and longitudinal stability of the F-4 aircraft has resulted in the following conclusions:

(a) The incremental drag of one GBU-15 CWW was improved by a Drag Index of approximately 2.6.

(b) The longitudinal stability of the F-4 was greatly improved by the smaller canards. Depending upon the altitude, the GBU-15 CWW Stability Index Number was reduced by approximately 50 percent at M = 0.85.

(c) The final, and most important conclusion, is that weapon designers must take into consideration the aircraft/store compatibility problems associated with the various design trends of modern nonnuclear guided weapons. As illustrated in this report, and noted in Reference 4, weapon designs have a very large impact on all aspects of aircraft/store compatibility. Design changes that affect store aerodynamics could significantly affect weapon separation characteristics or aircraft performance, stability or control.

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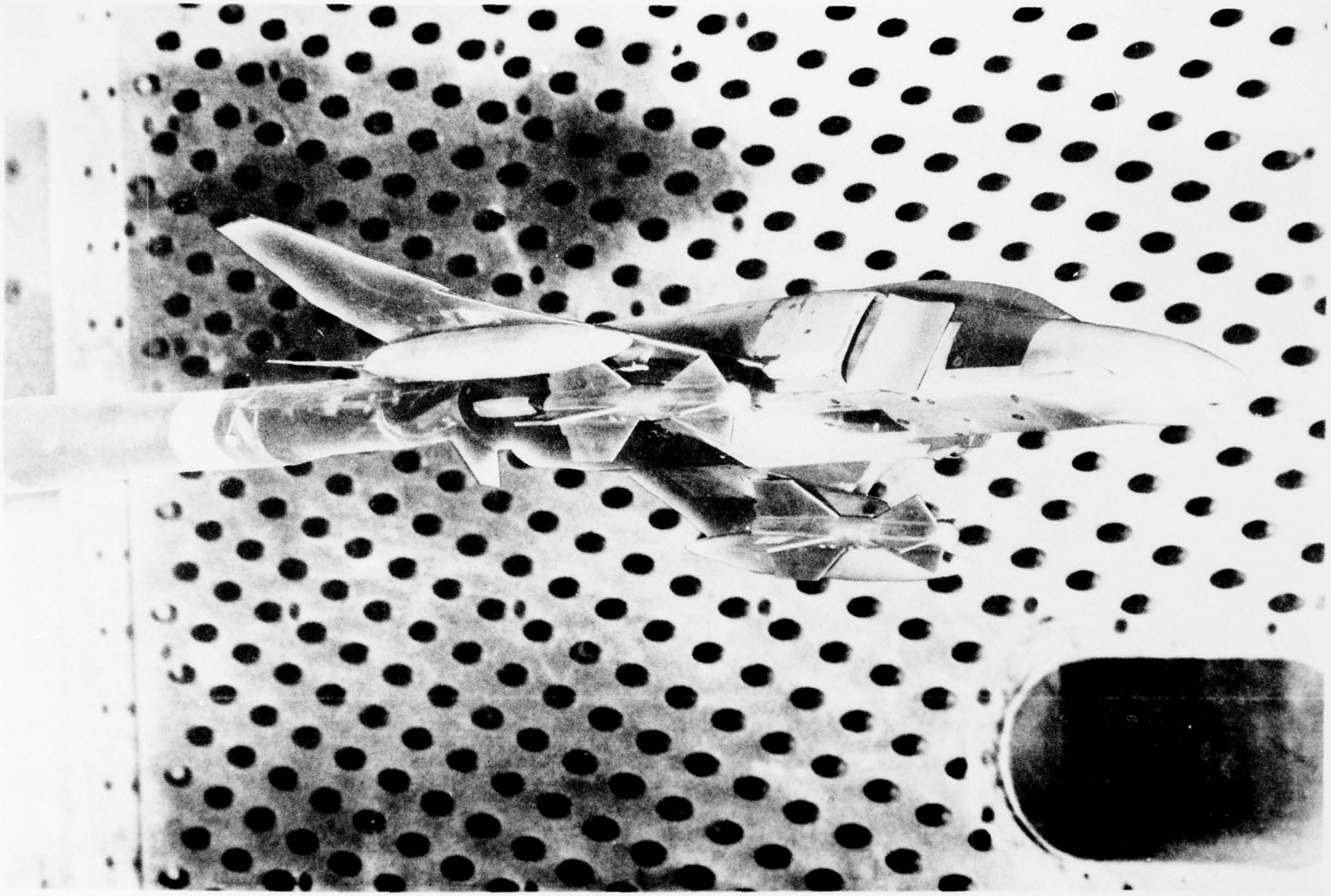

Figure 1. F-4C Model With GBU-15 Cruciform Wing Weapon (Large Canards) and 370-Gallon Fuel Tanks

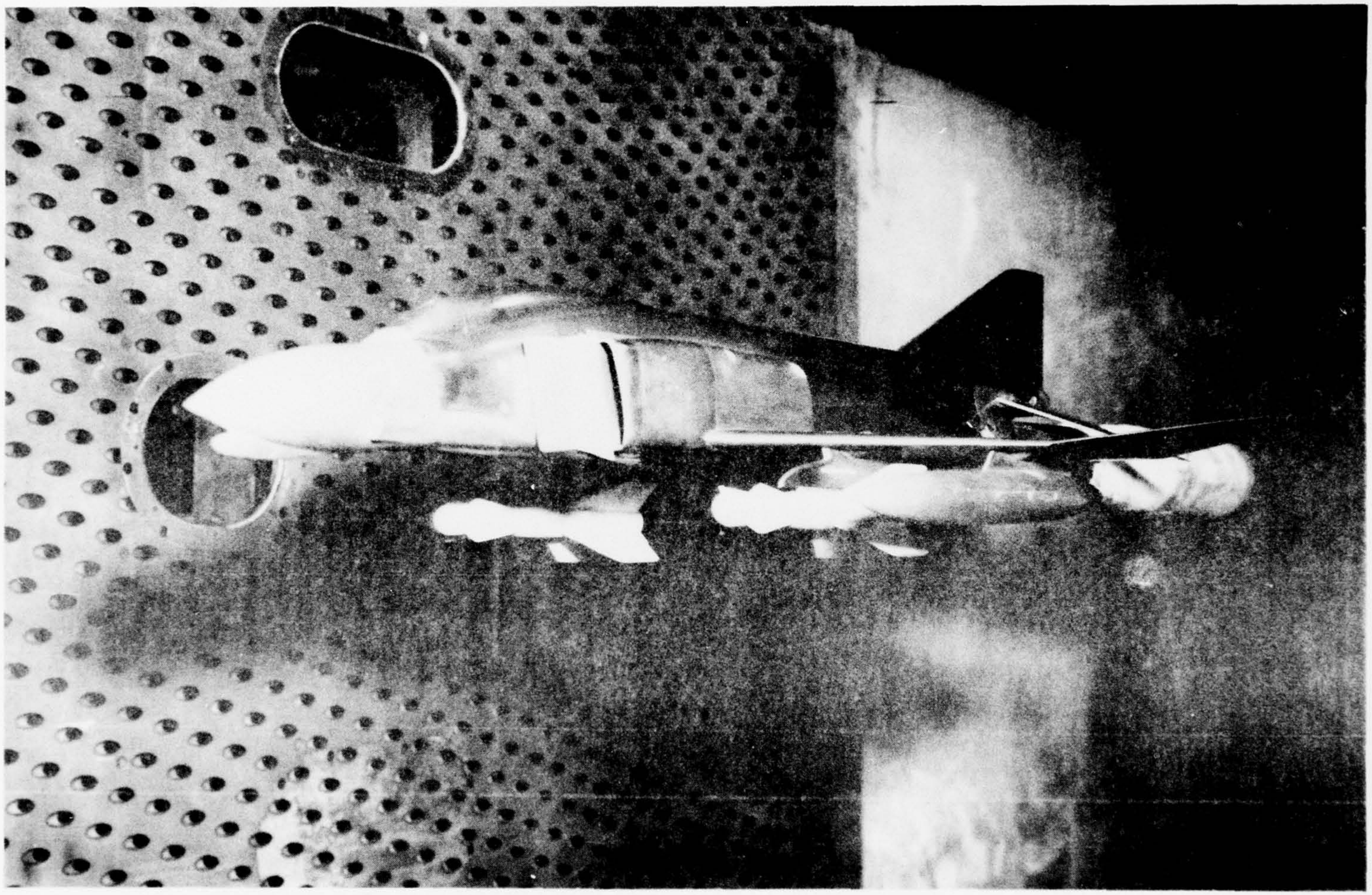

Figure 2. F-4C Model With GBU-15 Cruciform Wing Weapon and 370-Gallon Fuel Tanks

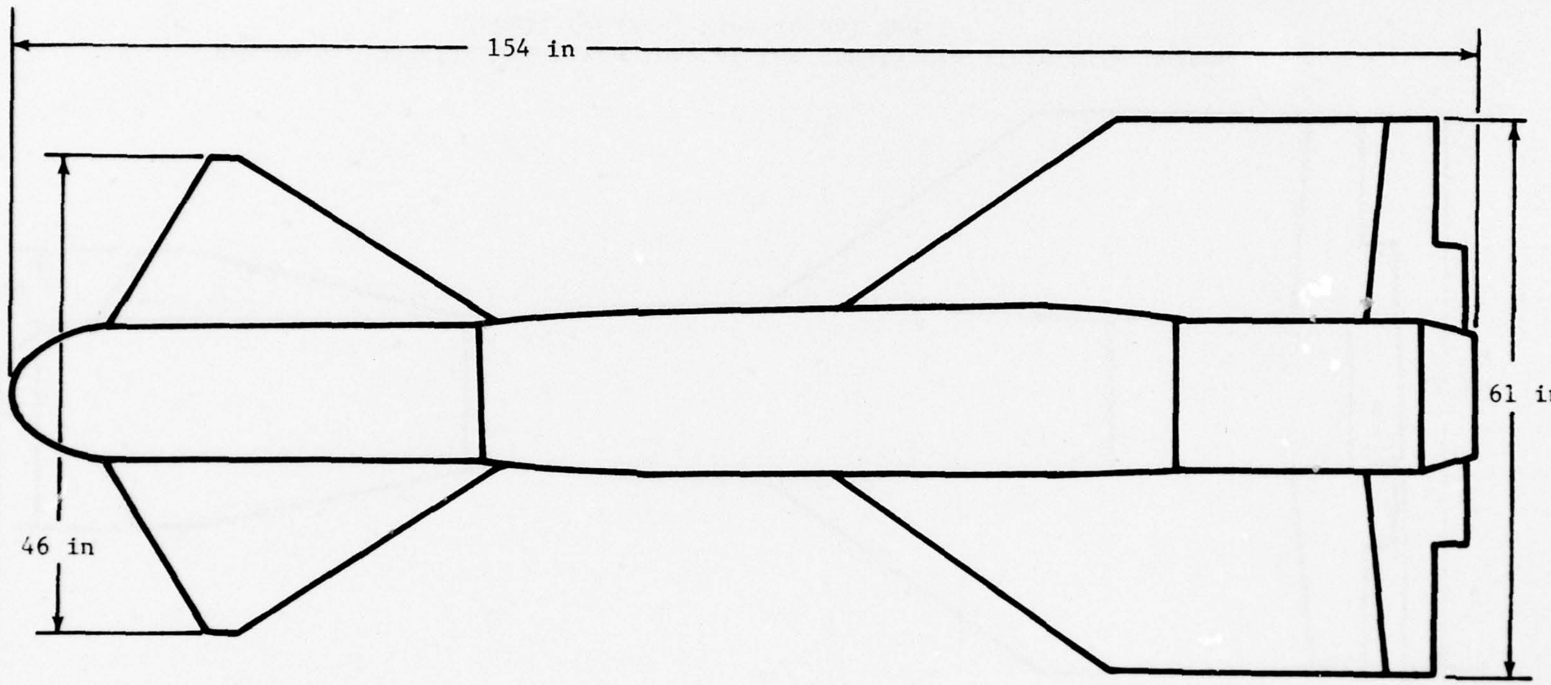

Figure 3. Details and Dimensions of the GBU-15 Cruciform Wing Weapon (Large Canard) Wind Tunnel Model

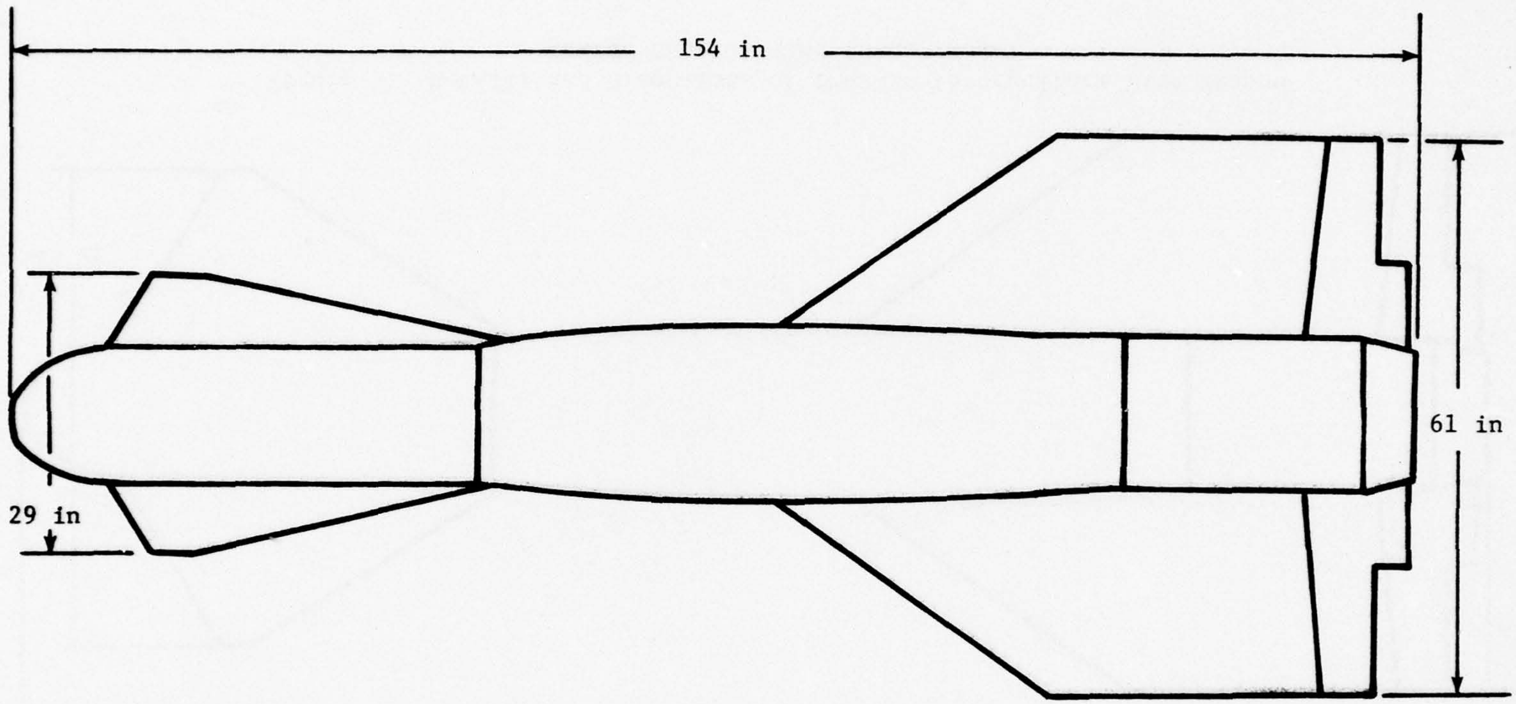

Figure 4. Details and Dimensions of the GBU-15 Cruciform Wing Weapon (Small Canards) Wind Tunnel Model

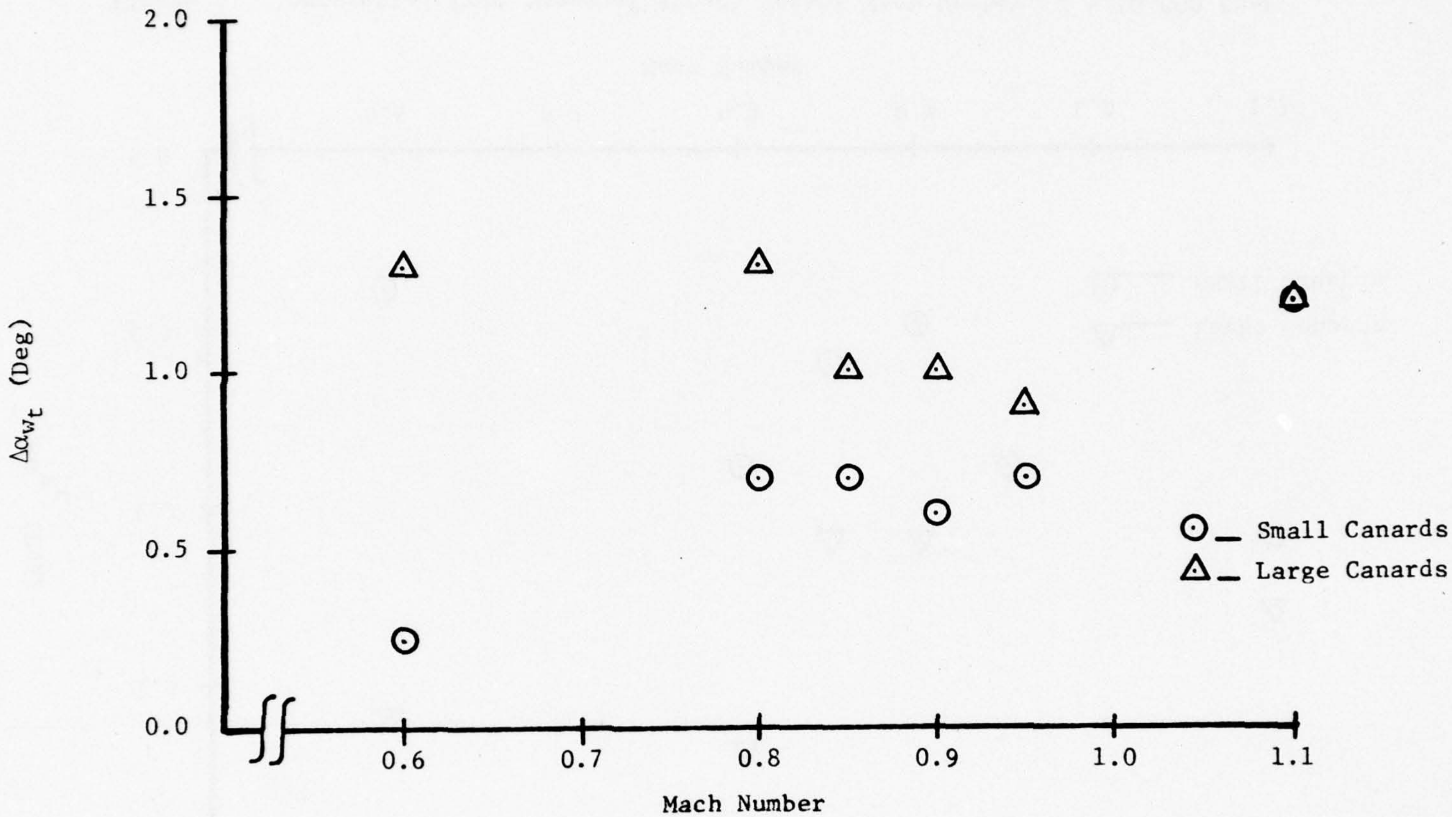

Figure 5. Incremental Trim Angle of Attack Versus Mach Number, H = Sea Level

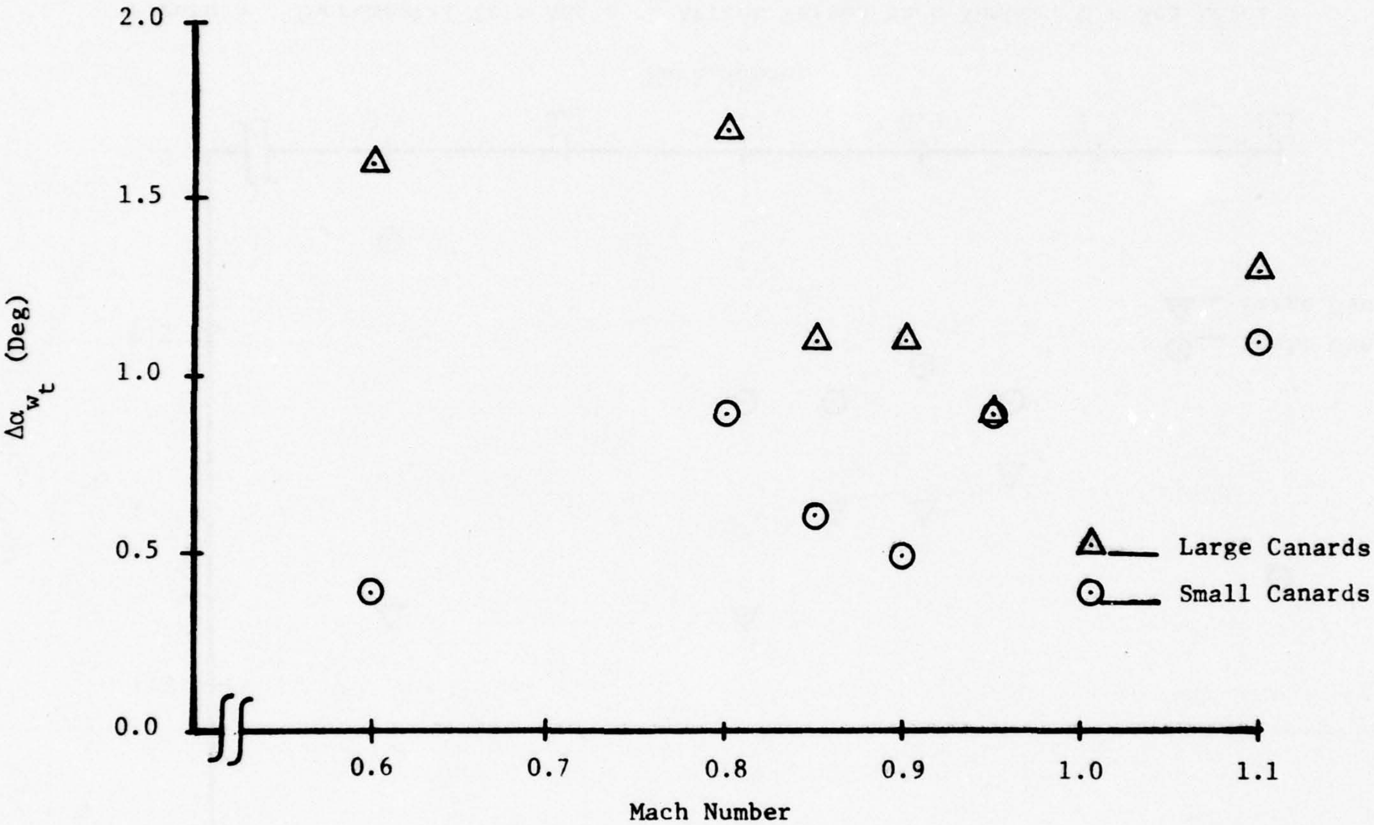

Figure 6. Incremental Trim Angle of Attack Versus Mach Number, H = 10,000 Feet

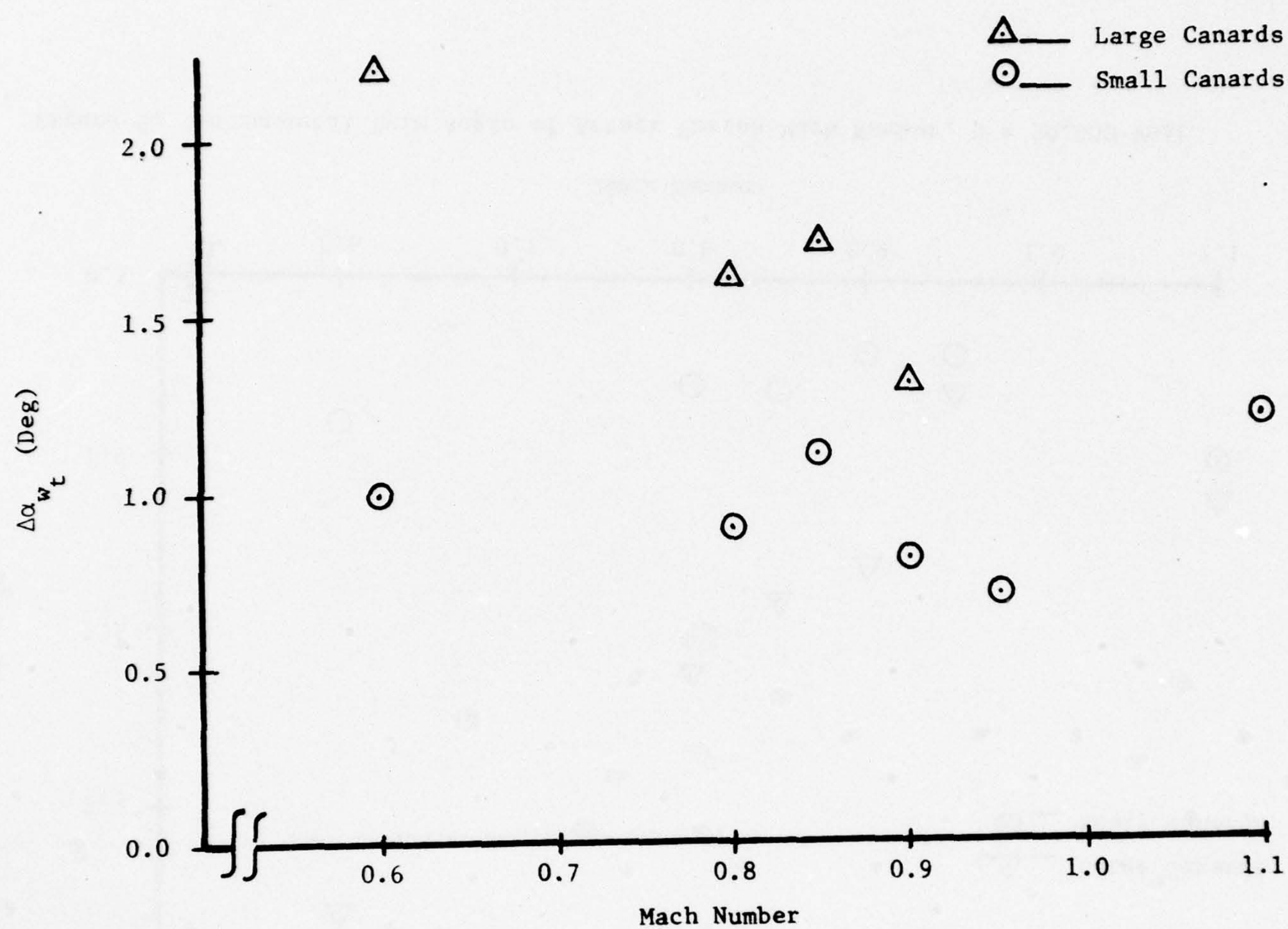

Figure 7. Incremental Trim Angle of Attack Versus Mach Number, H = 20,000 Feet

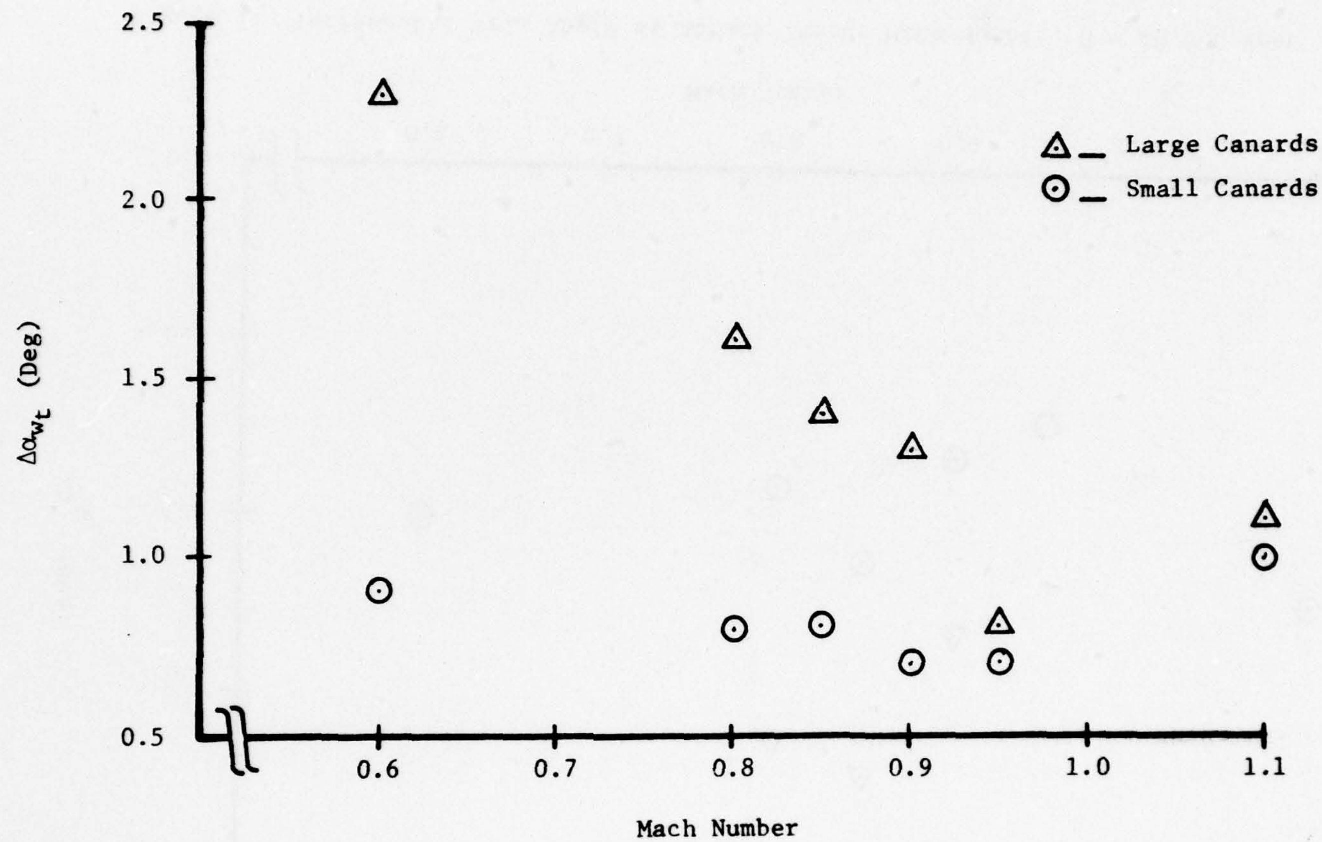

Figure 8. Incremental Trim Angle of Attack Versus Mach Number, H = 30,000 Feet

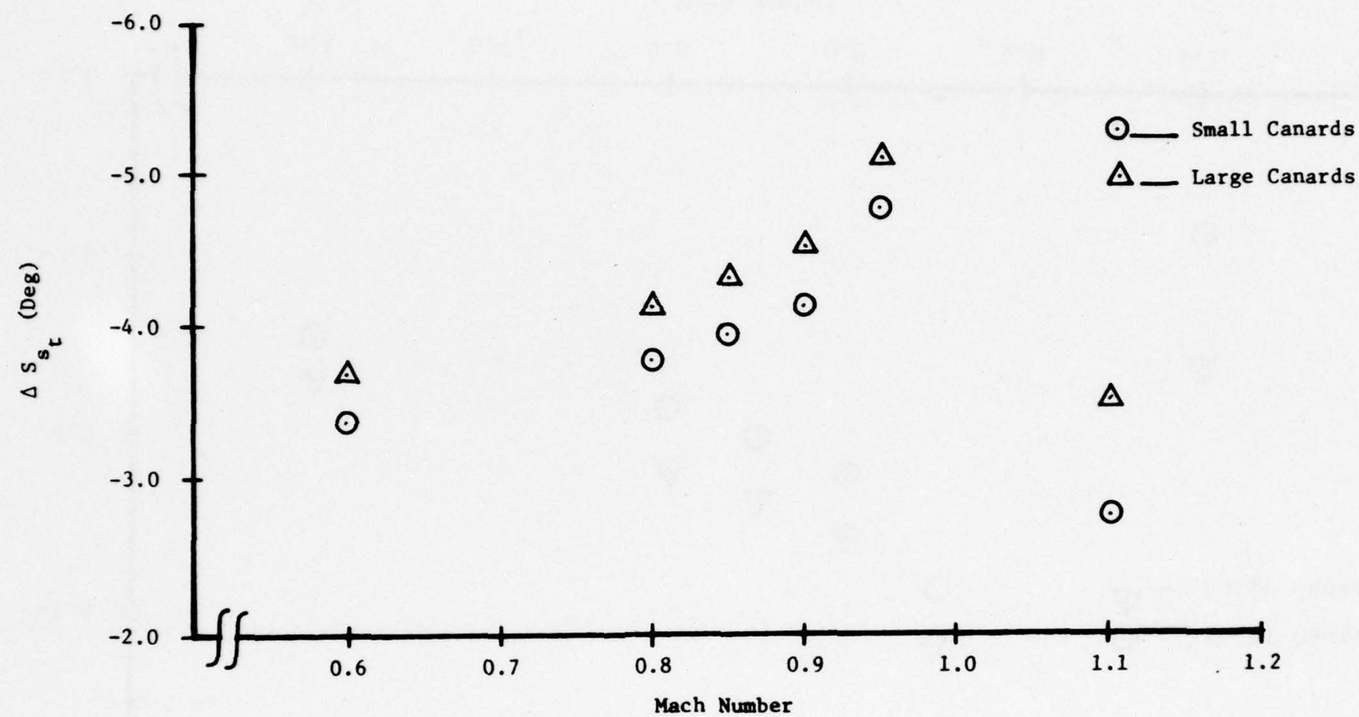

Figure 9. Incremental Stabilator Angle to Trim Versus Mach Number, H = Sea Level

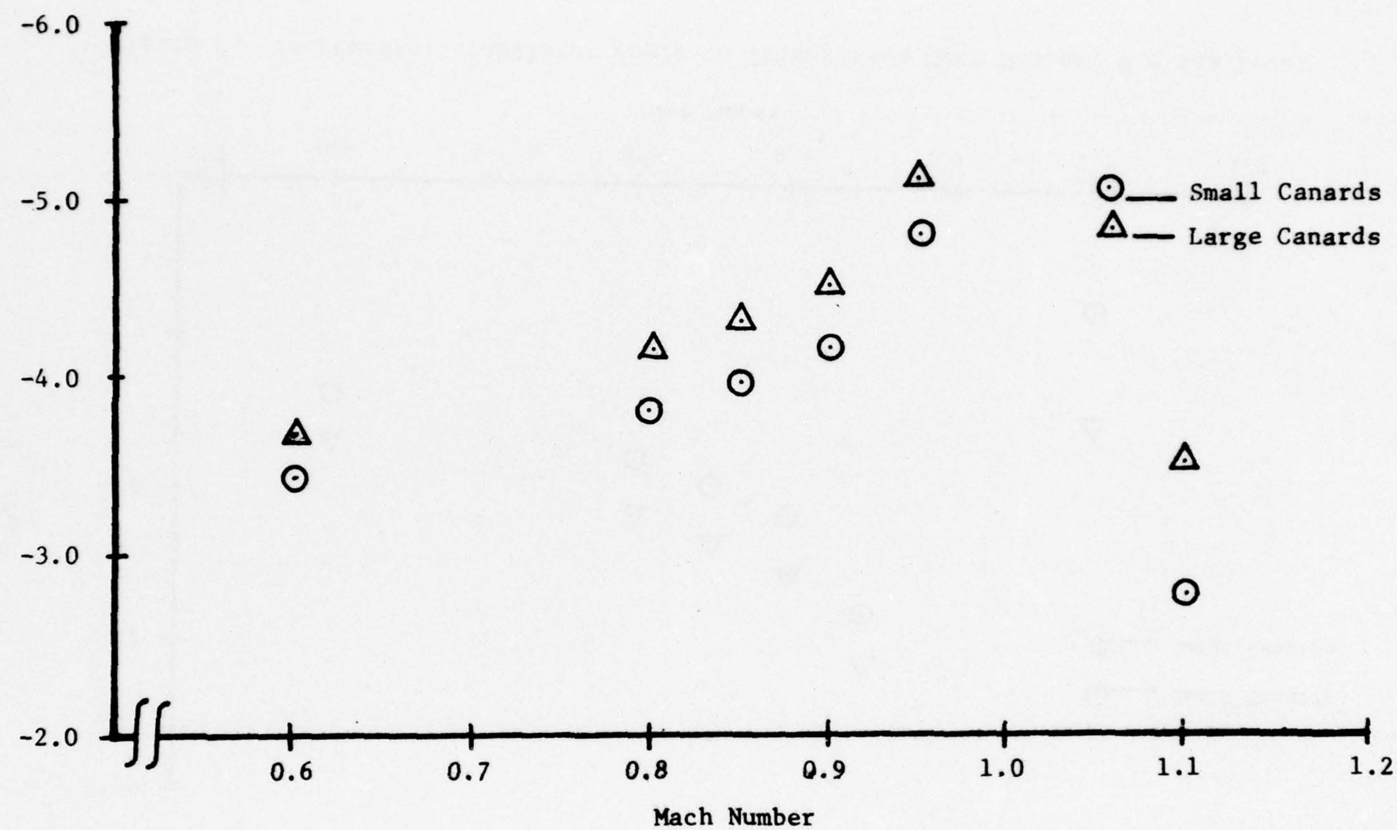

Figure 10. Incremental Stabilator Angle to Trim Versus Mach Number, H = 10,000 Feet

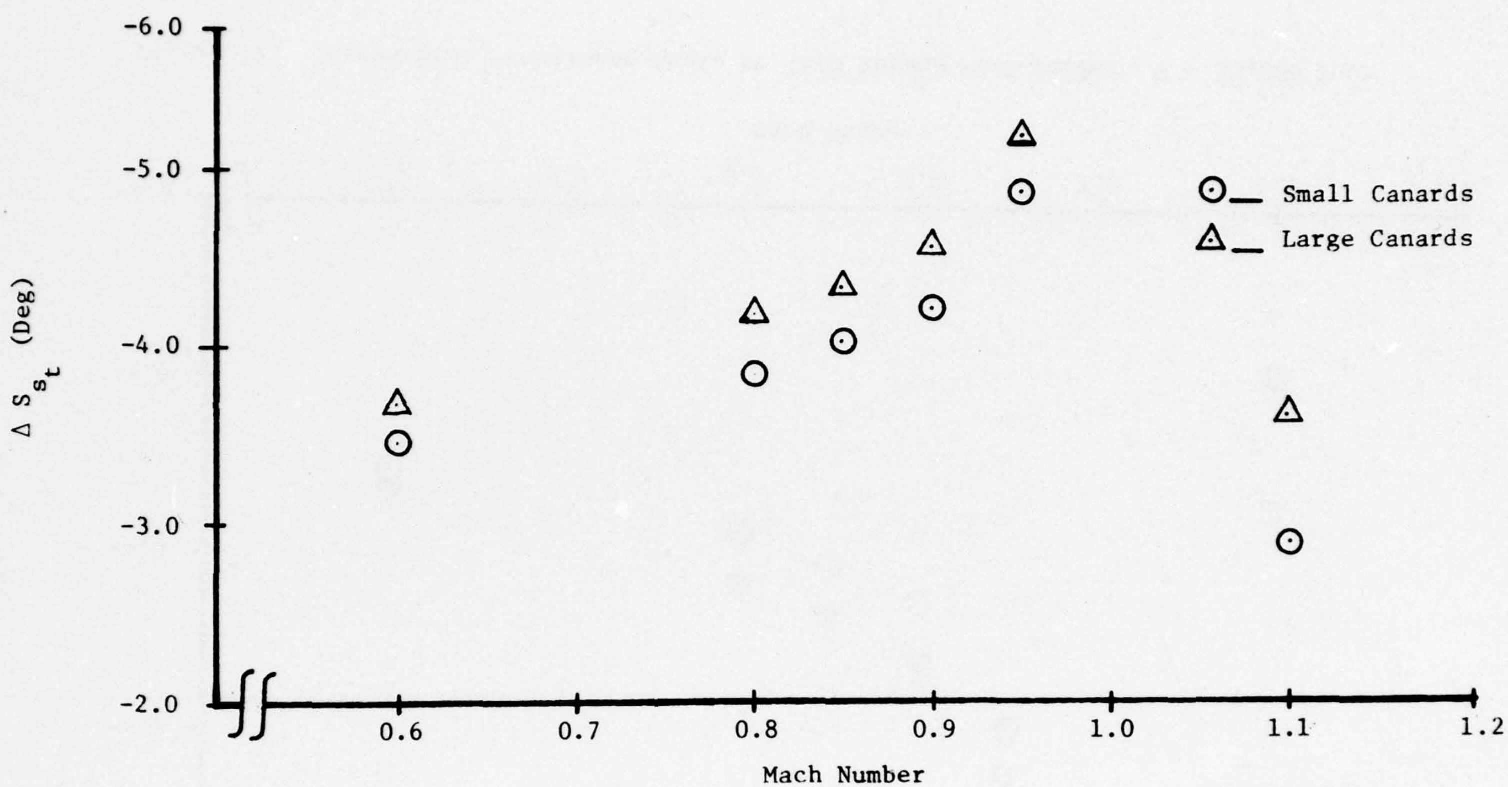

Figure 11. Incremental Stabilator Angle to Trim Versus Mach Number, H = 20,000 Feet

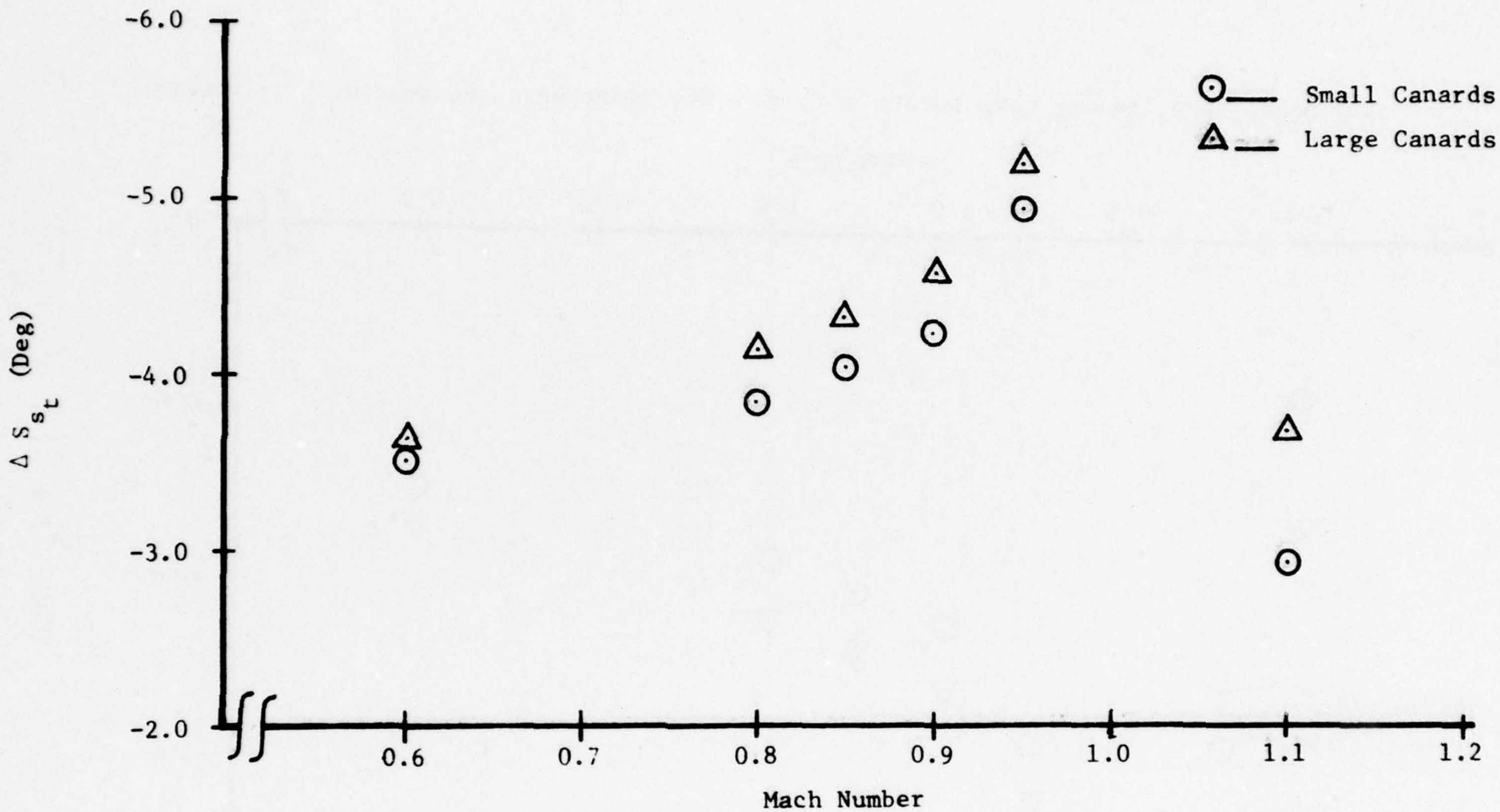

Figure 12. Incremental Stabilator Angle to Trim Versus Mach Number, H = 30,000 Feet

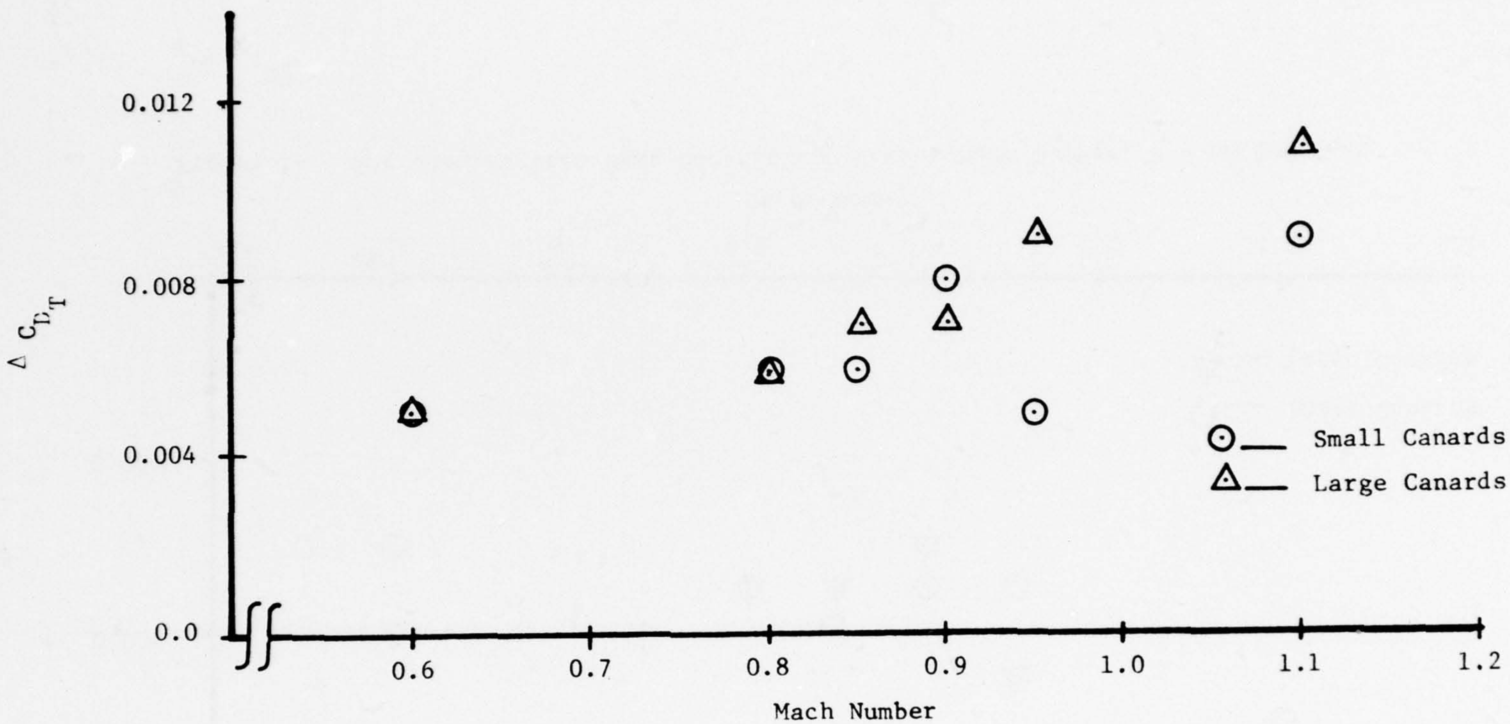

Figure 13. Incremental Trim Drag Coefficient Versus Mach Number, H = Sea Level

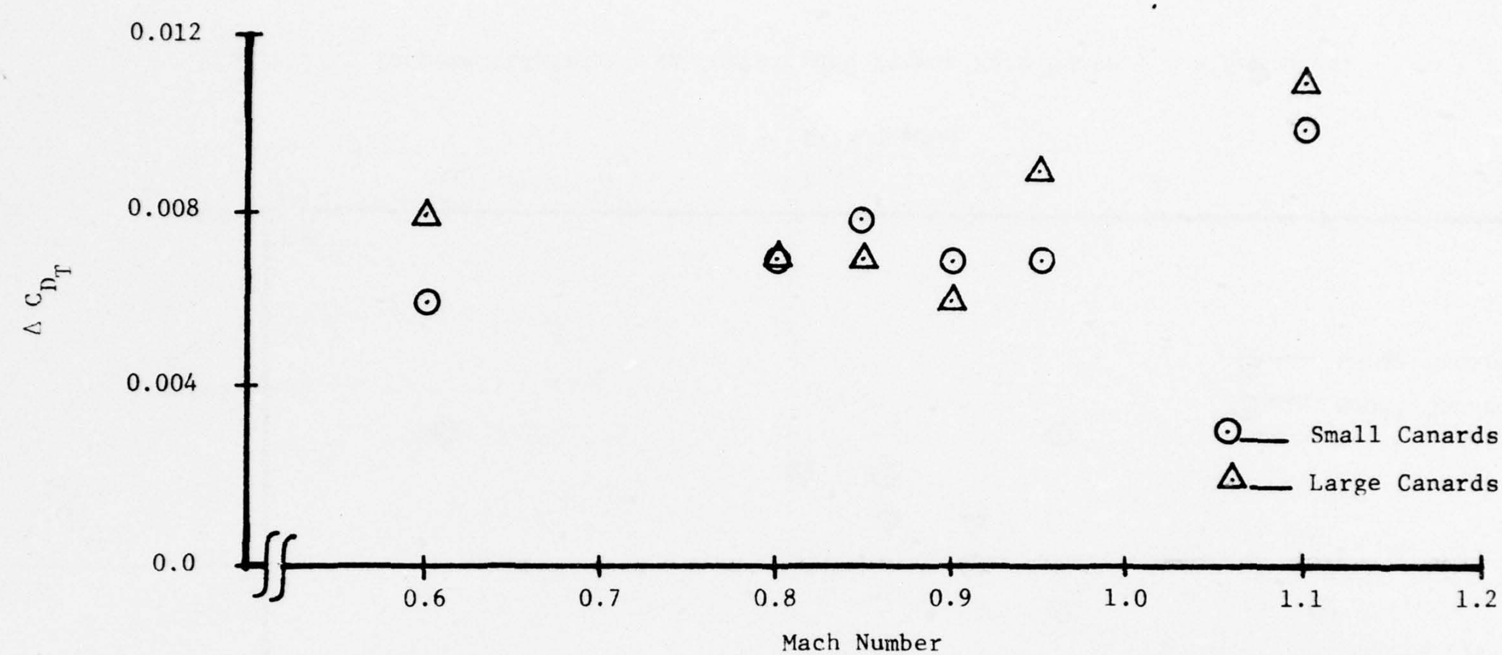

Figure 14. Incremental Trim Drag Coefficient Versus Mach Number, H = 10,000 Feet

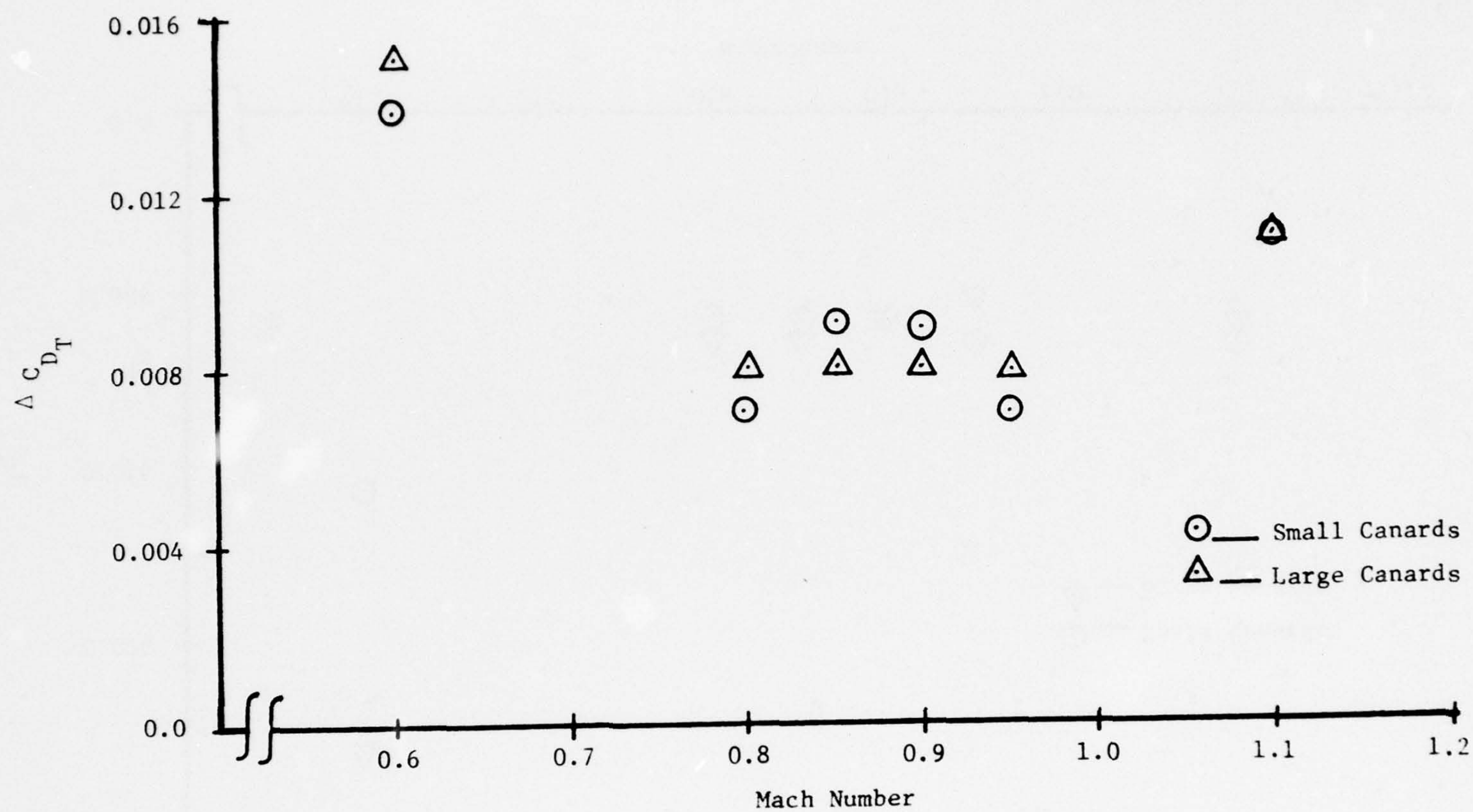

Figure 15. Incremental Trim Drag Coefficient Versus Mach Number, H = 20,000 Feet

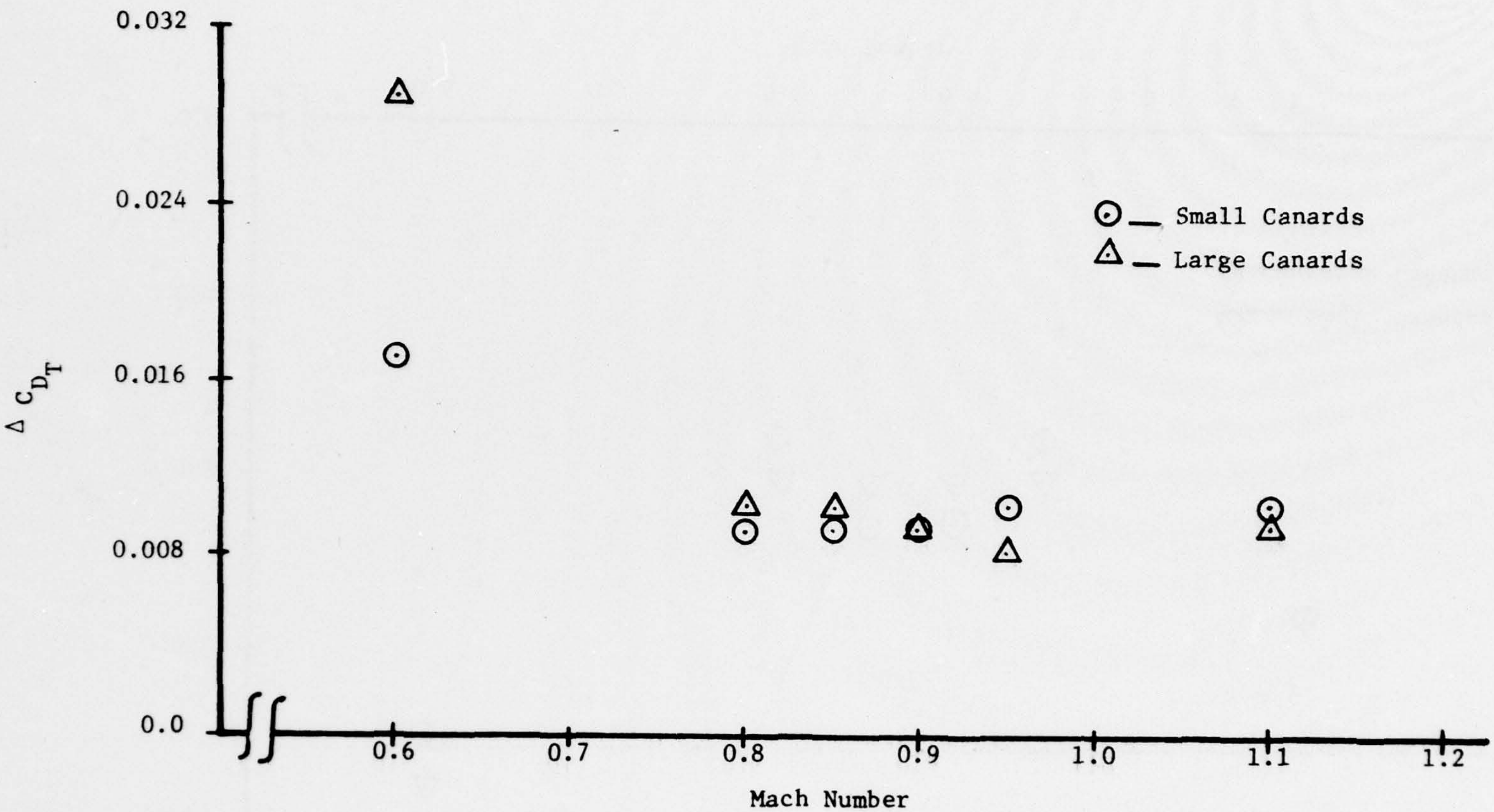

Figure 16. Incremental Trim Drag Coefficient Versus Mach Number, H = 30,000 Feet

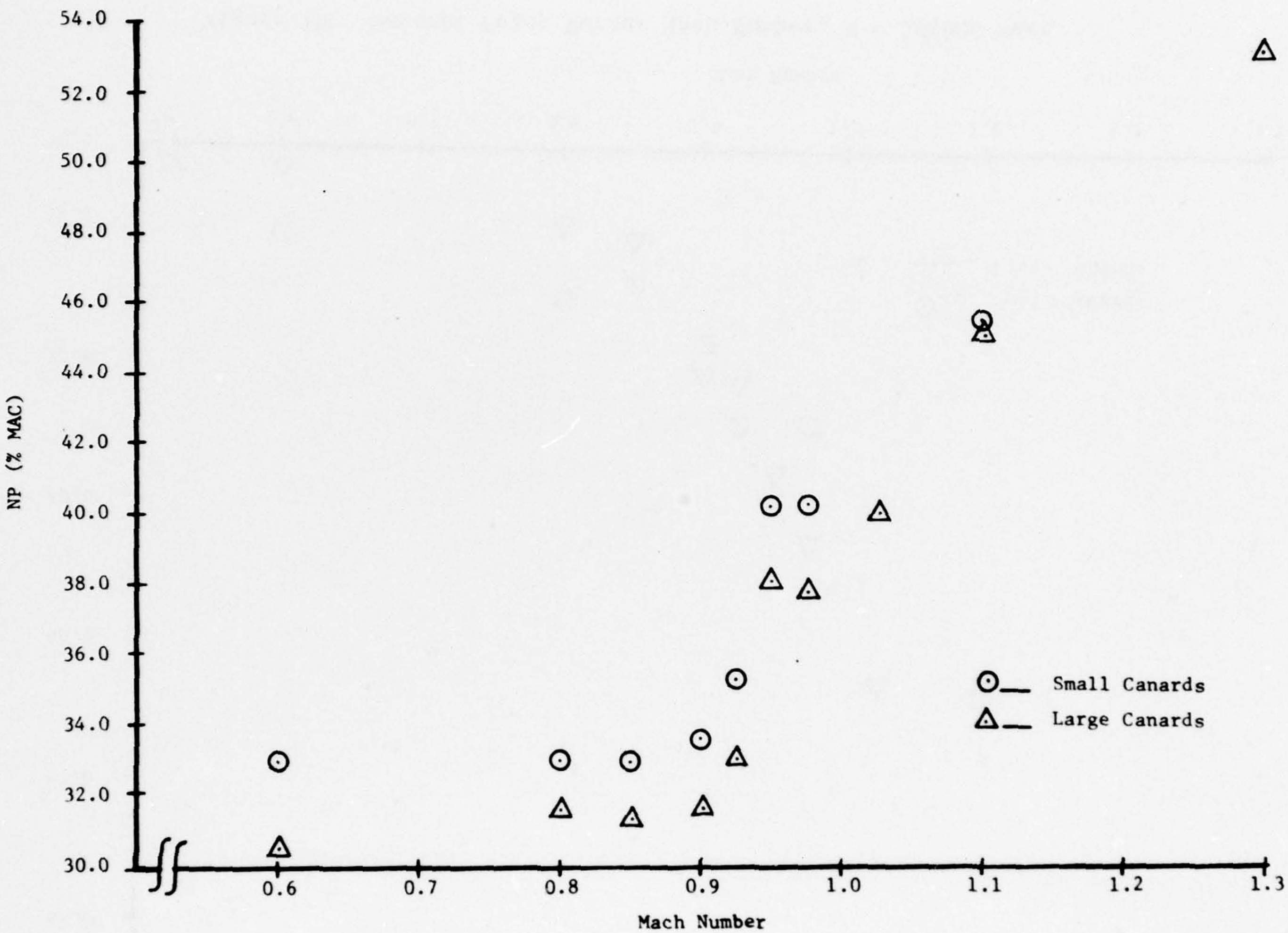

Figure 17. Neutral Point Versus Mach Number, H = Sea Level

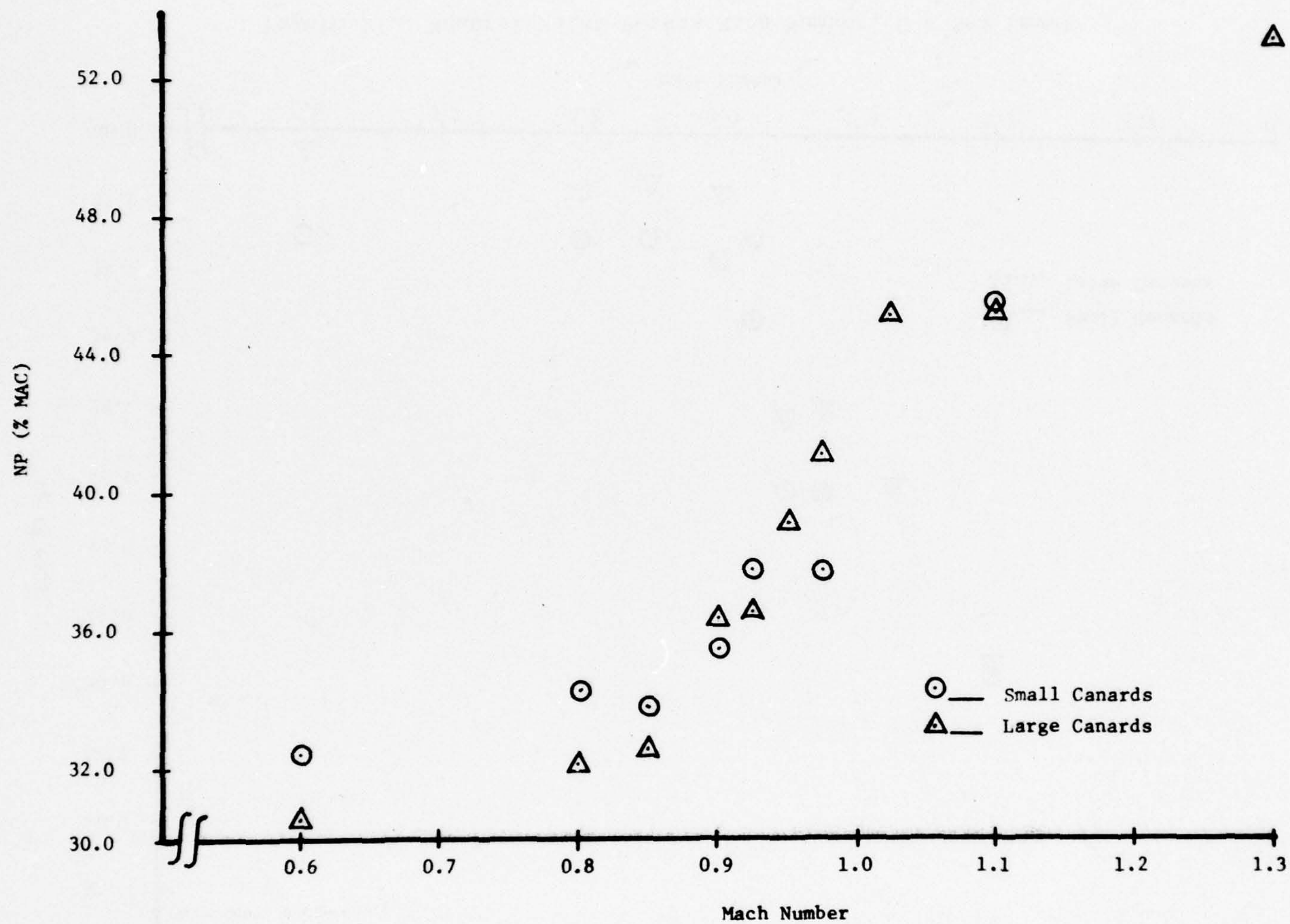

Figure 18. Neutral Point Versus Mach Number, H = 10,000 Feet

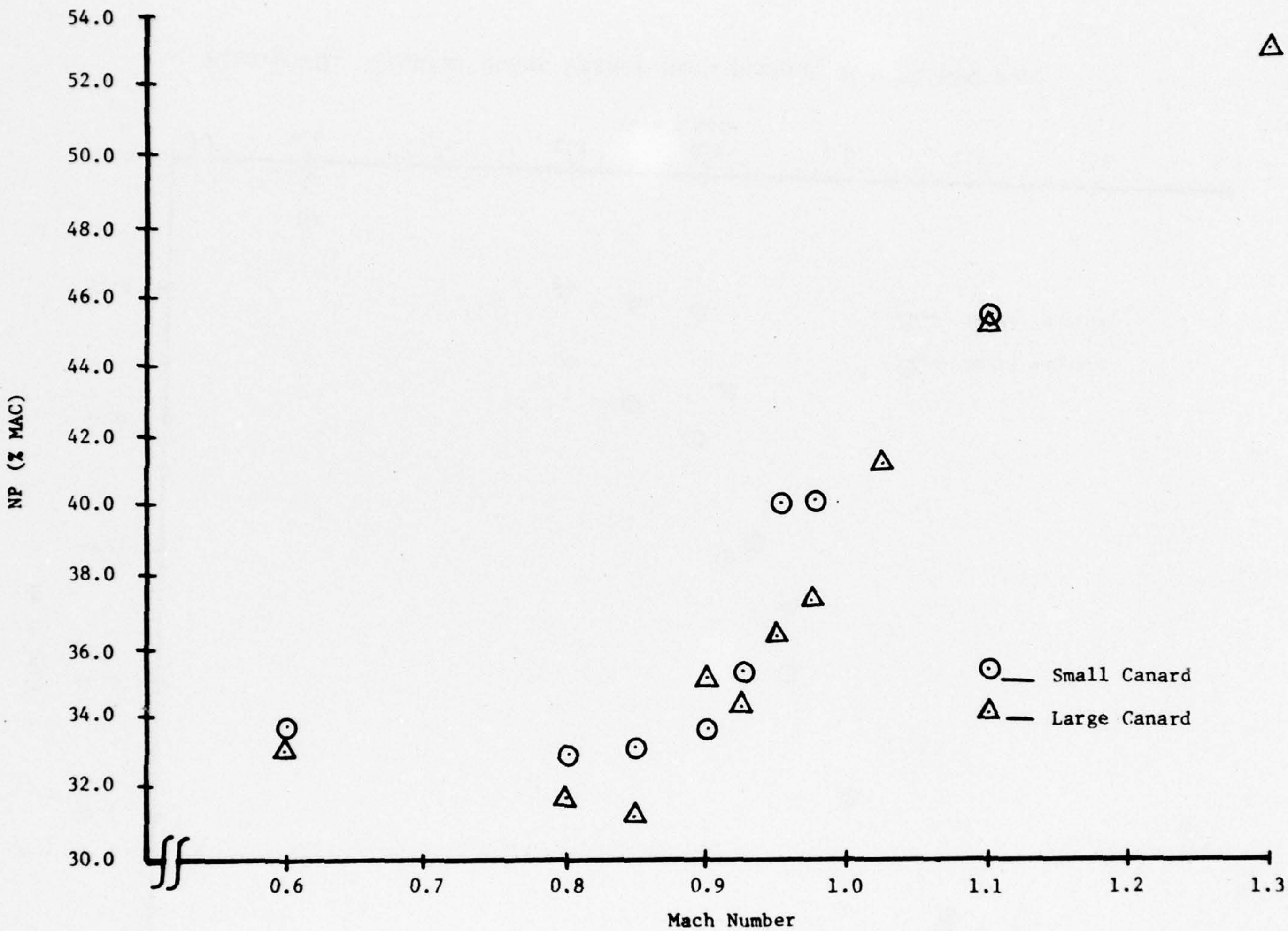

Figure 19. Neutral Point Versus Mach Number, H = 20,000 Feet

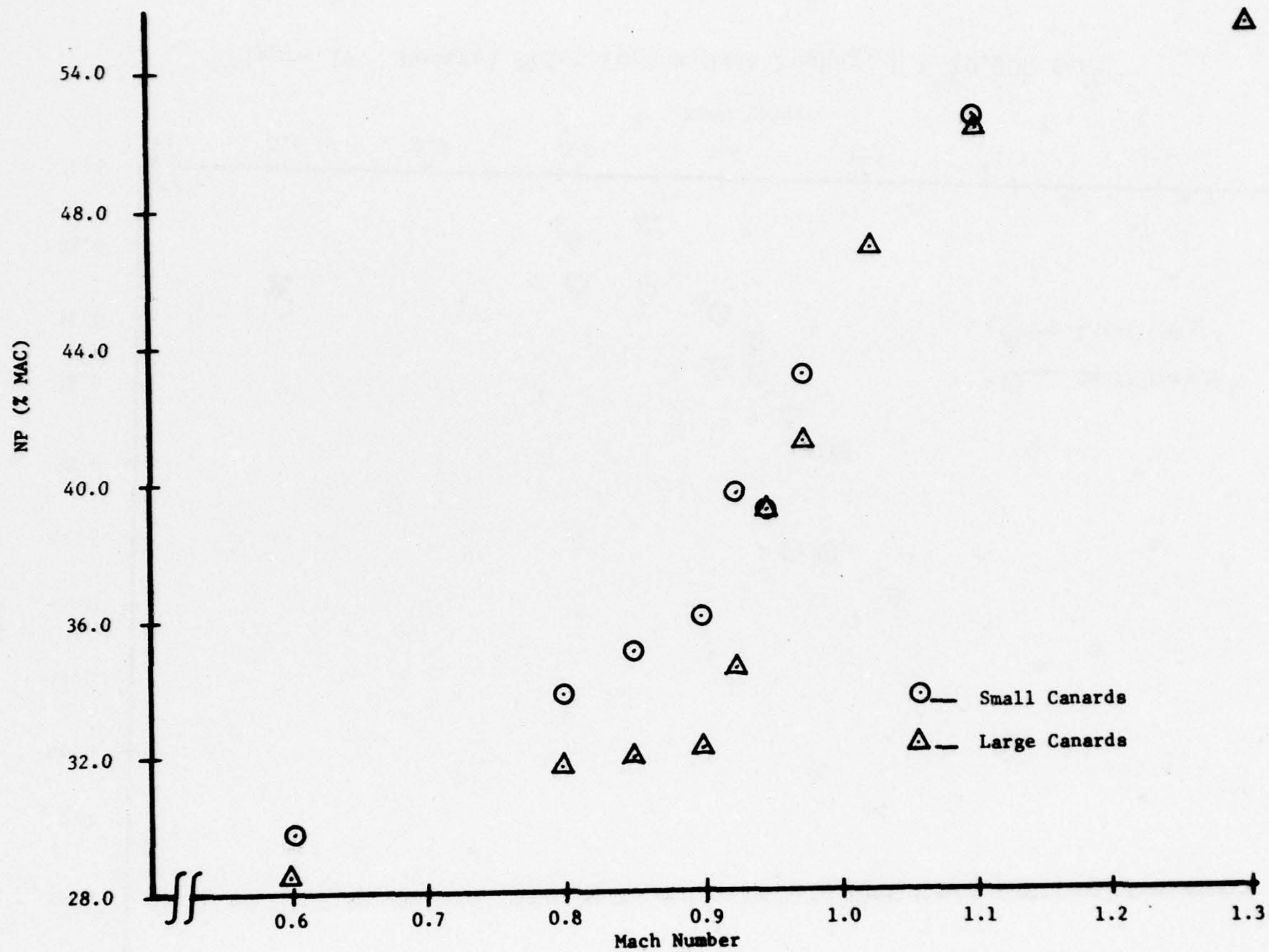

Figure 20. Neutral Point Versus Mach Number, H = 30,000 Feet

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